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Prasad, Ramjee

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FUTURE NETWORKS AND TECHNOLOGIES SUPPORTING INNOVATIVE COMMUNICATIONS

Ramjee Prasad

the Center for TeleInfrastruktur, Aalborg University, Aalborg 9220, Denmark
Prasad@ es.aau.dk

Abstract: Within a fully interconnected world, the distinct relationship between end users, consumers and providers rapidly changes towards a scenario of collaboration and competition of multiple parties within one system. 'Convergence', 'ubiquitous' and 'smart' are key words describing future networks and applications. This paper focuses on the technological aspects of ubiquitous networking and communication technologies, including challenges related to green communications, and security, privacy and trust. The paper proposes a novel concept for a Wireless Innovative System for Dynamically Operating Mega-communications (WISDOM) that combines the aspects of personal- and cognitive radio- networks to let seamlessly bridge the virtual and physical worlds offering a constant level of all-senses, context-based, rich communication experience over fixed and wireless networks for the end users while realizing a new generation of ubiquitous communications with a speed of more than 1Tbps.

Keywords: New generation communication networks; Ubiquitous communications; Interconnectivity

1 Introduction

Today, there are countless devices at work to improve productivity and quality of life of human beings, in all technological domains. In most cases these devices operate in isolation or with very little cooperation among each other, and serve a well-defined single purpose for which they have been engineered. The recent advances of device manufacturing and communication technologies have enabled personalization and mobile connectivity of a plethora of various devices, making those 'smart' and their penetration is expected to grow exponentially in the next years. Such growth is already creating an unprecedented opportunity for novel applications and services that go far beyond the mere purpose of each user, but are based on interconnectivity and interworking. Users are benefiting from services in the public or private sphere, while more and more personalized digital content is being generated. This novel scenario of connectivity and mobility is shown in Figure 1.

In principle, all the things of the world can be empowered to become "smart" and communicate with other peers or remote systems to better serve their purpose. However, if a cost versus benefit trade-off is considered, we can expect that smart things will, more likely, gradually enter the domains showing an inherent complexity, where smart things create substantial economical or social benefits with respect to current practices.

Figure 1 Connectivity and mobility scenario delivering smart applications.

A common aspect of these smart applications is that many of them of practical interest involve control and monitoring functions, where human-in-the-loop actions are not required while efficiency, security, and safety of the applications are improved.

Therefore, the future communication infrastructure is about capturing data, analyzing it to seek out efficiencies, and invoking an autonomic response to instantly capture those efficiencies. Networks will be the single, most indispensable element of binding individual societies, industries, economies, and humans, building an infrastructure of large-scale, complex and highly networked systems whose efficiency, sustainability and protection would require intelligent, interoperable and secure information communication technology (ICT) solutions and novel business models.

The concept of the Wireless Innovative System for Dynamically Operating Mega-communications (WISDOM) [1] is proposed to provide ubiquitous terabit wireless connectivity enabling human-centric mega-communication applications over a dynamic, interoperable and secure network. WISDOM is developed to enable the growth of an interconnected society, bridge the physical and virtual worlds by offering a seamless personalized rich digital experience for the end users, while creating the optimal conditions for capitalizing on Future Internet innovations.

The drivers for the performance requirements of future networks are highly dependent on the user requirements imposed on both devices and technology. The main user requirements and related devices and technology trends, are shown in Table I.

Table I User requirements on mobile devices and technologies

User requirements	Devices	Technology
Portability Trendiness	Minituarisation Innovative design and use cases	Capacity
Stay connected anytime, anyhow	Integration with evolving Internet: semantics, Web2	Pervasiveness, heterogeneity, Enhanced to ubiquitous coverage and capacity, lower latencies
Capturing various data with mobile device	User interactivity with environment	Pervasiveness, Transparency, Heterogeneity Connectivity, Capacity

It can be concluded that capacity, connectivity, and pervasiveness are key enablers of satisfying the user requirements. In turn, these drive the emergence of new environments that evolve from the gradual development and combination of present day cellular communications, Internet of Things (IoT) and Internet of Services, towards a more advanced vision of fully reprogrammable mobile devices, able to communicate with each other autonomously based on a given event context and part of a scale-free self-organized communication system. Significant breakthroughs in the state-of-the-art are required to attain this level of performance leading us to what can be characterized as a new paradigm for future systems, namely WISDOM.

2 Smart applications enabled by WISDOM

For most of the smart applications, data is collected by end nodes and needs to be sent to an interconnected ‘smart’ application platform through communication networks. This is shown in Figure 2.

Smart applications can use a variety of nodes and communication networks to collect and send data, respectively. The gateway plays the key role of connecting the heterogeneous in nature devices with network/platform/application. A group of devices can connect to a single gateway, and different devices may adopt different transport and application protocols.

Although today, it is possible to realize short-term smart applications (e.g., intelligent transportation; patient monitoring, smart grid), the scenario is characterized by each application having its own specialized chain from sensing to control, the latter happening on a dedicated remote center. While each application brings significant economic, environmental, and social benefits, such situation is sub-optimal due to limitations, such as scalability, security, quality of service (QoS) provision, and reliability.

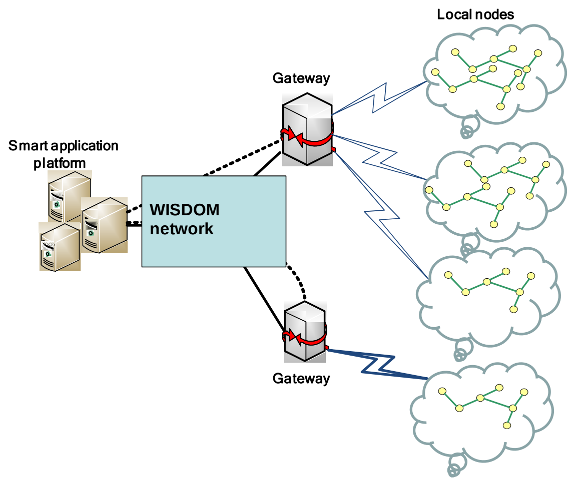

Figure 2 Delivering smart applications over the WISDOM communication network.

Each smart application will be part of a scenario in which participants will form an autonomous system, differing in size, capabilities and roles that would communicate with other autonomous systems as a result of local independent decisions based on a particular context. There are no ways to predict the extent of growth of the number of smart applications that could be requested by the numerous interconnected smart devices. To support local independent decisions, rich knowledge is required that must be inferred by the fusion of data in heterogeneous domains. This is very challenging considering the vertical, closed structure of current systems, where databases and operating centers are owned by different subjects, which might be unwilling to share the data, especially at the fine-grained resolution necessary for many control functions, because of business, legal, and trust concerns.

In order to overcome the above limitations, faster and ubiquitous communication technologies, novel supporting network architectures, autonomous features of each system component, and novel service architecture supporting fast and flexible service composition are required.

3 WISDOM

WISDOM offers the vision of future communication wireless networks that would make the pillar for enabling smart communication infrastructure, which will offer services and applications of data rate more than Tbps. The WISDOM architecture supports a physical layer where nodes are smart, can be identified uniquely, are interconnected and can connect to a global network infrastructure through various technological means. Connectivity is based on the use of broadband wireless communication technologies, with an increased use of short-range communication links realizing ultra-high bit rate. It can be assumed that these links will operate in burst mode reaching rates up to the terabit level over very short ranges. The human-centric vision of WISDOM is to provide each user with ubiquitous, personalized network access, at very high sustainable data rates approaching the Ethernet current state-of-the-art (10+ Gbps) reaching up to 1 Tbps in bursty mode. A ubiquitous and pervasive wireless network offering consistently 10 Gbps can be used as an alternative to Ethernet and an access network to Tbps fiber networks. A possible scenario for this operational domain is the "sync-n'-go" application, or "your-own-pocket-Internet" on a burst, with very fast downloads from hotspots, e.g., a movie about 10 GB, transmitted in less than one second when you pass with your "multimedia cell" over a portal. The whole network becomes a fast burst intelligent environment, thanks to the high-speed short range portals widely available.

With the huge number of devices that are expected to use the Internet in the future, the ability of self-management is an essential feature. Moreover, most of these devices will not have a user in the background to manage their actions. Most of them will be things with simple functionalities, but at the same time, they should respond differently depending on the context that surrounds them. In order to solve this problem, WISDOM will require not only novel PHY layer technologies but also advances towards cognitive network architecture. At the global internetworking level, clusters of cognitive networks represent a new category of access networks that need to be interfaced efficiently with the wired network infrastructure both in terms of control and data. Use of semantic technologies to model the behavior of the WISDOM nodes will realize context-aware response and follow-up decisions.

End-to-end issues of importance include naming and addressing consistent with the needs of self-organizing networks, as well as the definition of sufficiently aggregated control and management interfaces between cognitive access networks and the core networks.

Diversity of QoS requirements must be supported by leveraging a number of shared communication and computational resources, which will be highly heterogeneous and constrained in a variety of manners: the wireless access will be characterized by limited and time-varying throughput and error rates; services in the physical world may be provided by devices which could be mobile, thus not always available, and energy-constrained. Support of QoS requires complex radio resource management mechanisms to operate at different time scales (i.e., service provisioning, runtime), and to comprise a general QoS model.

Another key enabler of the WISDOM vision is scalability. It was shown that WISDOM is a highly dynamic complex system. Sustaining an efficiency of information exchange in such a scenario, where due to the self-organization properties of the WISDOM nodes, the topology will be dynamically changing and the WISDOM nodes will have a scale-free degree of distribution, requires that the information sources will be topology-agnostic. For example, traditional routing approaches, used in the context of WISDOM would lead to severe overheads, and even might very well prove incapable of supporting the dynamics of the expected autonomous group interactions. A proper analysis of the WISDOM dynamics must be a key part of the WISDOM system design, which should have as a basic point a suitable scale-free model enabling the proper WISDOM information exchange.

4 Conclusions

From the growing reality of future network research and developments, we can distill the following types of smart applications:

→Applications with market value or social impact

→"Things as a service": The abstraction of smart objects (things) through data/device models, protocols and interfaces.

The concept of WISDOM provides the necessary environment for bridging the above two types of smart applications and for the services to be deployed and executed.

The applications that will be created using the WISDOM platform may use the contents and particularly the context of the information, as the element that guides through a highly heterogeneous and dynamic environment.

Reference

[1] R. Prasad, "WISDOM: Wireless Innovative System for Dynamically Operating Mega-communications ITU-T Technology Watch Report," to be published in 2012.